

Piezoelectric Bimorph-based Microvalve for Liquid-based Micropropulsion

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There exists a need for very low impulse bit, micro-Newton thrust level propulsion systems in order to provide the required pointing accuracies for the attitude control of the microspacecraft. Such micropropulsion systems require precisely controlled, extremely small propellant flow from a pressurized liquid propellant tank (50-300 psi). Microspacecraft systems are anticipated to have severely limited power budgets. It is therefore desirable to incorporate "low power" valves meeting all the requirements for micropropulsion. Previously reported microvalves meet the power requirements, but they do not meet all other requirements such as liquid compatibility, pressure range, leak rate, and/or response time. The author's group recently reported a high-pressure piezoelectric gas-valve technology, which is not liquid compatible. Significant efforts are required for the development of liquid-compatible microvalves to meet the micropropulsion requirements such as pressure range (50~300psi), leak rate (0.005 sccm/He), and response time (<10 ms).

The piezoelectric microvalve consists of a seat plate, a boss plate and an actuator. The actuator is isolated by the boss top-plate in order to provide the liquid compatibility. Major elements of the microvalve design include its seating configuration with narrow seat rings. The seating configuration is provided by an initial opening pressure attributable to the tensile stress in the silicon tether extended by the valve seat. The outer part of the boss plate is a metal-to-metal bonded to the seat plate. The boss-center plate covered by the silicon dioxide is slightly thicker than the outer part. This causes the boss-center plate to be pressed toward the seat plate by the stretched tether, enhancing a leak-tight valve operation. The piezoelectric stack bimorph actuator exhibits the block-force of approximately 4 N, providing the force to overcome the differential pressure in addition to the downward bending stress from the boss-top plate. Application of a potential to the actuator creates a channel between the two openings, allowing for the passage of fluids. Since the piezoelectric element is essentially a stacked capacitor, the actuator consumes an extremely low power when it is not moving, thus making it possible to achieve a nearly zero-power, normally-closed valve system.

The silicon components are fabricated mainly by deep trench etching process before and after depositing and patterning metal layers. The seating rings are defined on the valve seat. The seat wafer is then etched from the backside to open up vias for the ports. These are metallized and patterned to define the bonding surfaces. The boss (or valve flap) wafer is then patterned from the topside to define the boss, which is released in a final etch. A silicon dioxide layer is deposited and patterned on the boss-center plate, followed by the deposition and patterning of bonding metals on the outer part of the boss and seat plates. The boss and seat wafers are then bonded to create a sealed and yet variable passage between the inlet and the outlet. This microfabricated structure, together with the piezoelectric actuator, is the primary valve component. The piezoelectric stack actuator is then bonded onto the boss plate in a leak-proof, high-pressure tolerant metal packaging.